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RECRUITMENT OF RAINBOW TROUT IN THE HENRYS FORK OF THE SNAKE RIVER, IDAHO

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STUDY 13-UNIVERSITY STUDIES

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1995 Annual Report

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The Henrys Fork of the Snake River has long been renowned as one of the world's best rainbow trout (Oncorhynchus mykiss) fly fishing rivers. Since 1978, the river section from Island Park Dam to Riverside Campground has been managed under special regulations to protect the fishery, including catch-and-release since 1988. However, there has been a steady decline in the fishery in this section of river during this time period according to Idaho Department of Fish and Game (IDFG) population estimates and angler surveys. An increase in numbers of rainbow trout occurred in 1993 following the 1992 drawdown of Island Park Reservoir, but the fishery has begun to decline again. The causes of these fluctuations in the rainbow trout fishery are not well understood. Recruitment may have been limited by the loss of concealment cover resulting from overgrazing of aquatic macrophytes and siltation and dewatering of interstitial spaces. Prior to the screening of most of the discharge from the dam beginning in 1993, recruitment may have been augmented by the input of rainbow trout from Island Park Reservoir.

Much of the biology of the rainbow trout in the Henrys Fork remains unknown. The temporal and spatial variation of spawning has not been determined. Optimal and marginal habitat for juvenile rainbow trout has not been identified, nor has seasonal use of and movement among these habitats. Answers to these questions are necessary to begin to understand the recruitment dynamics of rainbow trout in the Henrys Fork.

The overall goal of this study is to develop an understanding of the processes affecting rainbow trout recruitment rates in the Henrys Fork of the Snake River from Island Park Dam to Riverside campground. We are investigating spawning activity, quantifying immigration of hatchery rainbow trout from Island Park Reservoir to the Henrys Fork, determining seasonal abundances and survival rates of juvenile rainbow trout in study sections, and quantifying movements of juvenile rainbow trout among these sections. With this information, we will evaluate the ability of the fishery to sustain itself.

STUDY SITE

The Henrys Fork of the Snake River from Island Park Dam to Riverside Campground was divided into the following five sections for sampling juvenile rainbow trout (Figure 1): 1. Box Canyon (mouth of Buffalo River to head of Box Canyon rapids; 4 km); 2. Last Chance (tail of Box Canyon rapids to Harriman north fence; 4 km); 3. Harriman State Park (Railroad Bridge to Osborne Bridge; 4.5 km); 4. East Harriman (Osborne Bridge to Pinehaven development; 6.1 km); and 5. Pinehaven-Riverside (Pinehaven development to Riverside Campground; 4.5 km). Two additional sections were searched for spawning redds. These were: 1. Island Park Dam to the United States Geological Survey (USGS) gauging station (0.25 km), and 2. the USGS gauging station to the mouth of the Buffalo River (0.35 km).

OBJECTIVES

1. To identify rainbow trout spawning areas in the Henrys Fork below Island Park Dam and quantify spawning activity therein.

2. To quantify immigration of hatchery rainbow trout from Island Park Reservoir to the Henrys Fork below Island Park Dam.

3. To determine seasonal abundances and survival and mortality rates of juvenile rainbow trout in study sections of the Henrys Fork.

4. To quantify movements of juvenile rainbow trout among study segments.

5. To develop a protocol of techniques used to accomplish the preceding objectives to facilitate their subsequent use by IDFG personnel for monitoring purposes. The protocol will detail the efficient and effective conduct of techniques and methods found to be useful during the course of the study; it will also describe methods that failed to produce useful data, and reasons for such failures.

METHODS

Estimates of Redd Abundance

Redd densities were estimated using distance sampling techniques (Buckland et al. 1993) and the computer program DISTANCE (Laake et al. 1994). Replicate transects perpendicular to flow were randomly selected within study sections. Locations of redds on either side of a transect of known length were recorded to estimate the effective area sampled and the density of redds. Locations were identified by perpendicular distance (m) from the transect to the redd center. An estimate of the total number of redds in a section was obtained by extrapolating the estimate of density across the total available spawning area within the section. In the Box Canyon and Last Chance sections, observations were also made parallel to the bank between perpendicular transects, on one side of the river or the other. These observations could not be used in the DISTANCE analyses, but provided additional information on the presence and absence of redds in these sections.

Seasonal Estimates of Juvenile Rainbow Trout Abundance

In 1995, there were three primary sampling periods, hereafter referred to as seasons, for juvenile (i.e., < 200 mm total length) rainbow trout as follows: spring (mid-May to mid-June), summer (August), and autumn (October). Visible-implant fluorescent-elastomer marks were used to identify capture seasons and capture sections. Each study section was assigned a different color as follows: 1. Box Canyon, blue; 2. Last Chance, red; 3. Harriman State Park, green; 4. East Harriman, yellow; and 5. Pinehaven-Riverside, orange. Another color was used for all sections to indicate year of first capture for the year beginning in the summer sampling season. The year mark was located in the right post-ocular area. In spring 1995, the year mark was blue and the season/section mark was in the left post-ocular area. In summer 1995, the year mark was changed to red and the season/section mark was also in the left post-ocular area. In autumn 1995, the year mark was red and the season/section mark was in the left pectoral fin margin. Any juvenile trout marked in spring 1995 and recaptured in summer or autumn 1995 was marked in the left pectoral or left pelvic fin margin, respectively. Any juvenile trout marked in summer 1995 and recaptured in autumn 1995 was marked in the left pectoral fin margin.

The visible-implant marks were tested at the Bozeman Fish Technology Center. On 6 April 1995, each of five colors was tested in two blocks of nine juvenile rainbow trout (n=90). One individual in each block was a control receiving no elastomer mark. Eight individuals each received two marks: one mark in the right post-ocular area (1) and one mark located either in the left post-ocular area (1), pectoral fin margins (2), pelvic fin margins (2), anal fin (1), or upper or lower caudal fin (2) for a total of nine mark locations. Fish were anesthetized with tricaine methanesulfonate (MS-222) prior to marking. Marks were injected with a 3-cc syringe and 27-gauge needle and either a pectoral or an adipose fin was clipped. Each individual was inspected for marks on 13 April and 13 May 1995.

Juvenile rainbow trout were collected with boat-mounted electrofishing gear (continuous DC, 175-250 V). The elastomer marking procedure was similar to the experimental procedure described above. Secondary sampling period capture histories were indicated by a unique fin clip for each sampling date. Fin clips were minimized to allow mark recognition among secondary periods and regeneration between seasons. A proportion of hatchery juvenile rainbow trout stocked in Island Park Reservoir received an adipose clip to identify reservoir fish that have migrated to the Henrys Fork. All trout collected were inspected for marks to estimate abundance and survival, identify movement among sections, and identify hatchery rainbow trout originally stocked in Island Park Reservoir. Only juvenile trout 60-200 mm were marked with elastomer.

Juvenile trout were captured in all sections during spring by drifting with electrofishing gear along either bank and through mid-stream channels for two to six runs per date (Table 1). An individual capture history for secondary sampling periods was obtained for each juvenile rainbow trout; capture histories were used in models to estimate abundance. Effort was not equal among dates.

Bank samples were collected in spring with a hand-held probe operated from the boat electrofishing gear. Samples consisted of a one-pass removal along a known length of bank and were generally within 1 m of the bank and associated woody debris.

Summer mark-recapture sampling (Table 1) in Box Canyon, Last Chance, and Harriman State Park was confined to bank-to-bank sample areas about 100 to 120 m long. Sample area 1 of the lower 2.5 km of Box Canyon was downstream of the meadow and sample area 2 was between the waterfalls and the head of the Box Canyon rapids. Sample area 1 of the upper 2 km of Last Chance was downstream of the boat ramp and sample area 2 of the lower 2 km was downstream of the irrigation diversion. Sample area 1 of Harriman State Park was about 0.7 km downstream of the Railroad Bridge. Juvenile rainbow trout were captured in eight transects perpendicular to the current in each sample area by wading with boat-mounted electrofishing gear. Mark-recapture sampling in Pinehaven-Riverside was also confined to a sample area about 100 m long, but juvenile rainbow trout were captured in ten transects parallel to the current by drifting with electrofishing gear. Effort was equal among sampling dates in all sections.

A three-pass removal method was used for summer bank samples in the upper 1.5 km of the Box Canyon section and in the Pinehaven-Riverside section. In East Harriman, collections were taken by drifting through the entire section to determine if juvenile rainbow trout were present before marking and recapturing in a sample area as in Pinehaven-Riverside. Additional collections were obtained by drifting in Harriman State Park and Pinehaven-Riverside to mark fish with elastomer for survival and movement estimates.

In autumn, mark-recapture sampling in area 1 in Box Canyon and in all sample areas in Last Chance and Harriman State Park duplicated techniques used in summer. Area 2 in Box Canyon was not sampled. Bank samples in the upper Box Canyon and Pinehaven-Riverside consisted of a three-pass removal and an independent one-pass removal (i.e., on a different date before or after the three-pass removal). Juvenile rainbow trout were collected for marking in

East Harriman by drifting through the entire section. Additional collections to mark fish with elastomer were obtained by drifting in Harriman State Park and Pinehaven-Riverside.

A robust capture-recapture design was used to estimate seasonal abundances and survival rates of juvenile rainbow trout. The population (in a statistical sense) was considered open between primary sampling periods and closed between secondary sampling periods. The Jolly-Seber model was used with data pooled from secondary periods within primary periods to obtain estimates of survival. Estimates of abundance were obtained for secondary periods using the Lincoln-Petersen (Ricker 1975) and the modified Schnabel (Ricker 1975) estimators, and the computer program CAPTURE (Otis et al. 1978; White et al. 1982; Pollock et al. 1990; Rexstad and Burnham 1991). CAPTURE uses closed population models that allow for unequal capture probabilities. The program considers a range of different models allowing for capture heterogeneity, behavioral response, and temporal variation, and includes an objective method for selecting the most appropriate model. A complex interaction of population size (N), capture probability (p), and number of sampling periods is required for model selection to work. N must be sufficiently large (e.g., 50), p must be greater than 0.1, and five or more sampling periods are optimal.

Individual capture histories are required for primary periods to use the Jolly-Seber model and for secondary periods to use CAPTURE or the modified Schnabel method. Alternatively, data from secondary periods can be pooled into early and late samples to use the Lincoln-Petersen method. In situations where model selection is poor (e.g., low capture probabilities), the Lincoln-Petersen method may be preferable to CAPTURE (Menkins and Anderson 1988). If CAPTURE results are unreliable, either a Lincoln-Petersen or a modified Schnabel estimate was chosen based on maximizing the number of recaptures used by the estimator and on how conservative the estimate was.

CAPTURE was used to analyze three-pass removal data to estimate numbers of juvenile rainbow trout along sections of riverbank. A mean of these estimates was extrapolated to provide an estimate of total abundance along each bank in a section.

RESULTS

Estimates of Redd Abundance

The DISTANCE analysis of redd observations on 27 April 1995 from Island Park Dam to the USGS gauging station resulted in an estimate of 28 redds (95% CI, 12-67). There was an insufficient number of redd observations in the other sections for DISTANCE to estimate redd density (Table 2). One redd was observed between the USGS gauging station and the Buffalo River on 27 April. A point estimate of 5 redds in this reach was obtained using an effective transect width of 7.52 m, estimated by DISTANCE using the redd observations in the Island Park Dam to USGS gauging station reach. On 17 April in Box Canyon, no redds were observed along 20 transects and along 4000 m parallel to either bank between transects. One redd was observed in Last Chance on 18 April yielding a point estimate of 23 redds, assuming an effective transect width of 7.52 m. This estimate, however, may be biased upwards because we observed no redds along 4000 m parallel to the banks. Increasing the effort from 1946 m along 20 transects to include the banks resulted in an estimate of 9 redds. The actual number of redds in the Last

Chance reach probably lies between these estimates. Apparently, most rainbow trout spawning occurred between Island Park Dam and the USGS gauging station.

Seasonal Estimates of Juvenile Rainbow Trout Abundance

Spring

In the Box Canyon, juvenile rainbow trout were found in greater abundance close to each bank rather than in the channel. The mean number of trout taken in a 10-m bank section by a one-pass removal was 20 on the east bank (95% CI, 17-23; n=6) and 4 on the west bank (95% CI, 2-12; n=6). An extrapolation of these estimates indicated a total abundance of 9,778 juvenile rainbow trout along the banks of Box Canyon (95% CI, 7,333-12,000). Whereas 263 juvenile rainbow trout were captured in 12 one-pass removals along 216 m of the banks in 2 d, only 185 juvenile rainbow trout were captured in 25 standard IDFG drifting runs in 7 d with a recapture rate of 1.6%. The drifting runs did not capture juvenile rainbow trout close to the banks because of the high current velocity. Three recaptures marked during these runs allowed calculation of a modified Schnabel estimate of abundance in the channel, which when added to the bank extrapolation, gave the total estimate of abundance reported in Table 3.

In Last Chance and Pinehaven-Riverside during spring, juvenile rainbow trout were not concentrated along the bank as in Box Canyon, but recapture rates were low in drifting run collections (5.3% with 152 total captures in Last Chance and 1.1% with 178 total captures in Pinehaven-Riverside). Juvenile rainbow trout were distributed across the channel in both of these sections. The Lincoln-Petersen method was used to estimate abundance in Last Chance and the modified Schnabel was used for Pinehaven-Riverside (Table 3). CAPTURE did not produce estimates of abundance for any mark-recapture data because all capture probabilities were < 0.10.

No juvenile rainbow trout were captured during a daylight sample on 31 May in Harriman State Park. Three juvenile rainbow trout were captured in combined night samples on 1 and 3 June and 14 were captured on 11 June. There was an indication that immigration occurred between 3 and 11 June; macrophyte density noticeably increased and adult captures increased from 5 to 40. In East Harriman, seven juvenile rainbow trout were captured in combined samples from 2 and 4 June and four were captured on 10 June. There was no indication of immigration as in Harriman State Park. There was no noticeable change in macrophyte density and combined adult captures were 38 on 2 and 4 June and 30 on 10 June. The estimate of total abundance in spring did not include Harriman State Park and East Harriman because we concluded that abundances there were negligible.

A total of 801 juvenile rainbow trout were marked with elastomer during the spring sampling season (Table 4). The length-frequency distributions, by section, of 805 captures < 200 mm total length, suggested differences among sections (Figure 4), but we did not test the length-frequency distributions for statistically significant differences.

Summer

In the lower Box Canyon, the recapture rate was 2.5% with 202 total captures in 3 d in sample area 1 and 5.7% with 263 total captures in 3 d in sample area 2. The recapture rate was 5.1% with 312 total captures in 4 d in sample area 1 in the upper section of Last Chance and

0.7% with 150 total captures in 3 d in sample area 2 in the lower section of Last Chance. CAPTURE did not produce estimates of abundance for any sample area because all capture probabilities were < 0.10. Abundances of juvenile rainbow trout in the lower Box Canyon and Last Chance sample areas were estimated using the modified Schnabel method and extrapolated to estimate total abundance in each section (Table 3).

In the upper Box Canyon, the mean number of juvenile rainbow trout in a 10-m bank section was 8 (95% CI, 0-19; n=4). There was no difference in abundance between banks (Wilcoxon rank sum test; P=0.99). This estimate was extrapolated to the lengths of both banks of the upper Box Canyon to estimate juvenile rainbow trout abundance (Table 3).

In Harriman State Park, 62 juvenile rainbow trout were captured in one night on 9 September at sample area 1 and 11 juvenile rainbow trout were captured throughout the East Harriman section on one night on 8 September. Because summer conditions were ending, sampling was not continued in either section and no estimate of abundance was obtained. In Pinehaven-Riverside, 12 juvenile rainbow trout were captured in 3 d in sample area 1; no recaptures precluded abundance estimation. The total estimate of abundance in summer includes estimates from only Box Canyon and Last Chance (Table 3).

A total of 680 juvenile rainbow trout were marked with elastomer during the summer sampling season (Table 4). The length-frequency distributions by section of 1,201 total captures < 239 mm total length suggested an increase in total length from Box Canyon to Pinehaven-Riverside, but the length-frequency distributions still need to be statistically analyzed (Figure 5).

Autumn

In the upper Box Canyon, the mean three-pass removal estimate of the number of juvenile rainbow trout in a 10-m bank section was 22 (95% CI, 0-67; n=8). This estimate was extrapolated to the lengths of both banks of the upper Box Canyon to estimate total abundance in this section (Table 3). The variation in abundance among 10-m removal sections (SD=28.3) was about one order of magnitude greater than the mean section-specific variation (mean SD=2.88). There was a positive linear relation between paired one-pass and three-pass removals (P=0.0001, r^2=0.97; Figure 2), including seven observations from Box Canyon and two observations from Pinehaven-Riverside (one-pass removals of 1 and 2 paired with three-pass removals of 5 and 6, respectively). Six Box Canyon observations had one-pass removals ≤ 25 paired with three-pass removals ≤ 42. Removing the outlier, a one-pass removal of 68 paired with a three-pass removal of 148, reduced the correlation coefficient to 0.75, but the relation was still significant (P=0.006; Figure 3).

In the lower Box Canyon, the recapture rate was 11.6% with 326 total captures in sample area 1. The recapture rate was 10.4% with 643 total captures in sample area 1 in the upper section of Last Chance and 7.3% with 399 total captures in sample area 2 in the lower section of Last Chance. There were five marking dates in each area. In sample area 1 of Harriman State Park, the recapture rate was 6.6% with 242 total captures in 4 d. CAPTURE did not produce reliable estimates of abundance for any sample area because all capture probabilities were < 0.10. Abundances of juvenile rainbow trout in sample areas were estimated using the modified Schnabel method and extrapolated to estimate the total abundance in each section (Table 3).

In East Harriman, the recapture rate was 0.3% with 353 total captures in 2 d. Total abundance was estimated using the Lincoln-Petersen estimator (Table 3). Only 47 juvenile rainbow trout were captured in 2 d in Pinehaven-Riverside. The estimate of total abundance in autumn did not include Pinehaven-Riverside because we believed that the abundance there was negligible.

A total of 1,918 juvenile rainbow trout were marked with elastomer during the autumn sampling season (Table 4). Having completed three primary mark-recapture periods, survival rates for spring and summer could now be estimated using the Jolly-Seber model; the data will be analyzed in 1996. The length-frequency distributions by section of 2,498 total captures < 239 mm total length suggested an increase in total length from Box Canyon to Pinehaven-Riverside, but the length-frequency distributions still need to be statistically analyzed (Figure 6).

The mean recapture rate for three capture periods in summer samples was 3.0% (n=3), 5.8% (n=2) for four capture periods in summer and autumn samples, and 9.8% (n=3) for five capture periods in autumn samples. The mean number of captures for 3, 4, and 5 capture periods was 205, 273, and 456, respectively. The recapture rate was significantly greater for five versus three capture periods (Fisher's Least-Significant-Difference test, ranked data; P=0.02), but the number of captures was similar in three, four, and five capture periods (P=0.1). There did appear to be an increasing trend in number of captures as number of capture periods increased, but a significant trend may not have been detected because of small sample size. The number of recaptures in three and four capture-period samples ranged from 1 to 16 and ranged from 29-38 in five capture-period samples.

Mark Retention

One week after juvenile rainbow trout were marked with elastomer and fin clipped at the Bozeman Fish Technology Center, there were no mortalities and only one elastomer mark was lost, indicating a mark retention rate of 99.4%. One month later there were no mortalities and no more marks had been lost. In the field, 50 juvenile rainbow trout were recaptured in different seasons and 8 of 100 marks were lost, indicating a retention rate of 92%. Thus, 16% of recaptured fish could not be identified as to which season and location they were marked in.

Movement

Movement of marked juvenile rainbow trout was not detected between spring and summer (Table 5). Five fish marked in spring were recaptured in summer in the section they were marked in. However, juvenile rainbow trout in Harriman State Park were captured in greater numbers in summer compared to spring, suggesting immigration into this section had occurred. The origin of these juvenile rainbow trout is not known.

All juvenile rainbow trout marked in Harriman State Park and Pinehaven-Riverside in summer and recaptured in autumn had not moved from their respective section (Table 5). Most fish marked in summer in Box Canyon (80%) and Last Chance (88.2%) and recaptured in autumn also did not move; 20% of Box Canyon recaptures were in East Harriman and 11.8% of Last Chance recaptures were in Box Canyon (Table 5). More juvenile rainbow trout were marked in East Harriman in autumn than in both spring and summer (Table 4), also indicating that there was immigration into this section.

Movement of two juvenile rainbow trout was detected within seasons (Table 5). An individual captured in Last Chance in spring was recaptured in Pinehaven-Riverside, moving > 15 km in 18-24 d, and an individual captured in Last Chance in autumn was recaptured in Box Canyon, moving > 4 km in 10-14 d. However, there was also evidence that juvenile rainbow trout were not moving within seasons. Juvenile rainbow trout were consistently recaptured within the areas they were marked in all sample areas in Box Canyon, Last Chance, and Harriman State Park.

No juvenile rainbow trout we captured had an adipose clip. Thus there was no evidence that juvenile rainbow trout stocked in Island Park Reservoir had migrated into the Henrys Fork.

DISCUSSION

Estimates of Redd Abundance

Distance sampling techniques provided an unbiased sampling method to estimate the abundance of spawning redds. The method was particularly useful for sampling large-scale areas such as Box Canyon and Last Chance, where a traditional census was not feasible. The 1995 samples resulted in point estimates on single sampling dates in each section that suggest the spatial scale of spawning activity from Island Park Dam through Last Chance. Spawning activity was concentrated below Island Park Dam to the USGS gauging station. The temporal scale of spawning activity in the Henrys Fork can be determined by using this sampling technique at different time intervals during the rainbow trout spawning season. We found no references in the literature to the use of distance sampling for the estimation of spawning redd abundance; however, distance sampling techniques have been used to estimate abundances of benthic stream fishes (Ensign et al. 1995).

Seasonal Estimates of Juvenile Rainbow Trout Abundance

These estimates of abundance were for juvenile rainbow trout < 200 mm total length and not for cohorts. Age analyses will allow partitioning in the future to discern abundances of each age class in each section. A retroactive application of age analyses will partition 1995 abundances into age cohorts.

The 200 mm limit for juvenile rainbow trout was determined from length-frequency data of rainbow trout captured in Last Chance from October 1994 to February 1995. This data indicated that age 0 and age 1 cohorts were < 200 mm total length. The length-frequency of spring 1995 captures (Figure 7) suggested that age 1 rainbow trout may exceed 220 mm. Age analyses for each season will identify the correct maximum length for juvenile rainbow trout.

The sampling of entire study sections using mark-recapture techniques was not an effective method of estimating total abundance because capture and recapture rates were too low. High discharge from spring runoff compromised the effectiveness of drifting with electrofishing gear to capture juvenile rainbow trout.

Sampling bank sections in Box Canyon with hand-held electrofishing gear showed that juvenile rainbow trout were holding tight to cover. The current velocity was too high to allow sampling along the bank from a drift boat. The sampling of bank areas in Box Canyon, however, was very important in estimating total abundance because of the number of juvenile rainbow trout in these areas. It was also important to sample along both banks because the bank-to-bank temperature gradient appeared to affect the distribution of juvenile rainbow trout. The spring-fed Buffalo River caused higher temperatures and numbers of juvenile rainbow trout on the east bank than on the west bank, which received water from Island Park Reservoir that was 2.5-3 °C cooler.

The complex bank habitat in Box Canyon was not present in any other study section. Consequently, juvenile rainbow trout in other sections were not concentrated along the banks but distributed throughout the channel. Spring estimates in a section like Last Chance could be improved if samples were taken before the discharge increased using changes incorporated in summer and autumn samples.

Rather than sampling entire sections inadequately, smaller areas were sampled more intensively in summer and autumn. The number of captures increased such that juvenile rainbow trout could be collected in two sample areas per day with equal effort on each date. Wading with electrofishing gear across a transect was particularly effective in drawing juvenile rainbow trout out of macrophyte cover. Whereas juvenile rainbow trout tended to hold tight to cover as sampling gear approached, adult rainbow trout swam away and were not shocked and handled, allowing more time to mark juveniles.

The mean recapture rate in summer and autumn increased with the number of capture periods and individuals collected. Although sample size was small, the mean recapture rate was significantly greater with five rather than three capture periods. The change in numbers captured was not significant as capture periods increased but there was an increasing trend. Many 3- to

4-d periods occurred on consecutive dates whereas 5-d periods were distributed over 12 to 13 d. This may have been correlated to the increase in recapture rates, but still needs to be tested.

The computer program CAPTURE did not provide reliable estimates of abundance for mark-recapture data. The precision of estimates in mark-recapture sampling is strongly dependent on the number of captures and recaptures, both of which are influenced by capture probability, the number of capture periods, and the true abundance. The abundance estimates in this study were large (> 1,000). Consequently, capture probabilities were < 0.10, even when there were five capture periods. Increasing the number of capture periods may increase capture probabilities, but as the number of capture periods increase so does the risk of violating the closure assumption. In situations where capture probabilities are low, Menkins and Anderson (1988) suggest that the use of other estimators, such as the Lincoln-Petersen, are preferable to CAPTURE.

The probability of negative statistical bias exists in Lincoln-Petersen estimates if the number of recaptures is less than three and in the modified Schnabel estimate if the number of recaptures is less than four (Ricker 1975). When possible, estimators were chosen to avoid the likelihood of statistical bias. However, one to two recaptures were used in two Lincoln-Petersen estimates and two modified Schnabel estimates (Table 3). Although these estimates may have been negatively biased, the estimates did provide an indication of how many juvenile rainbow trout were present in the sampled study sections and the estimates were conservative.

A regression model was developed to predict three-pass removal estimates from one-pass removal data. Among-section sampling error was large relative to the error of section-specific abundance estimates. Increasing the number of bank sections sampled may decrease among-section sampling error. If one-pass removal data accurately predicts three-pass removal estimates, more bank sections could be sampled in a given amount of time. The model was significant at $\alpha=0.05$ with either eight or nine data points (Figures 2 and 3). Additional paired one-pass and three-pass removals will be needed to verify and strengthen the model, particularly where abundances are > 45 (Figure 3). Comparisons of models for each season will determine whether or not data from each season can be combined into a single model. Similar regression models have been used to estimate salmonid abundance in streams (Crozier and Kennedy 1994; Jones and Stockwell 1995), but we have not found such models developed for salmonids in large rivers.

Identifying the movement of stream salmonids over large spatial scales is inherently difficult (Gowan et al. 1994). By repeatedly sampling short study areas in Box Canyon, Last Chance, and Harriman State Park, and sampling in East Harriman and Pinehaven-Riverside, we were better able to detect the movement of juvenile rainbow trout. Other studies have not been able to detect long range movements because sampling was confined to one area (see review in Gowan et al. 1994). If a high proportion of fish in a single area were marked, resampling in that area would show restricted movement if marked fish were recaptured. This was evident in Box Canyon, Last Chance, and Harriman State Park sample areas (Table 5). However, by sampling in more than one such area, long range movements of juvenile rainbow trout were detected by recaptures in sections other than those they were marked in. Juvenile rainbow trout were less likely to be recaptured in areas they were not originally marked in, but this likelihood of recapture could be increased by sampling more areas or by sampling more intensively in fewer areas. Sampling intensively in fewer areas (but more than one) was preferred because of the increased probability of capturing juvenile rainbow trout that did not move while still being able to detect long range movements.

Visible-implant elastomer marks were effective in identifying seasonal capture periods and capture locations. Mark retention was ≥ 92% in both experimental and field situations. A disadvantage, however, is that a captured individual must initially receive two marks and an additional mark for each additional seasonal capture. The retention rate will decrease as a function of the total number of marks on an individual. For example, given a retention rate of 92% for an individual mark, a fish with four marks has a 72% chance of retaining all marks.

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Table 1. Sampling dates for juvenile rainbow trout in spring, summer, and autumn, 1995, in study sections of the Henrys Fork.

Study section	Dates sampled	Total (d)
	Spring	
Box Canyon	16-26 May	8
Last Chance	21-26 May	6
Harriman State Park	31 May-10 Jun[a]	4
East Harriman	2-11 Jun[a]	3
Pinehaven-Riverside	12-19 Jun	6
Total	16 May-19 Jun	27
	Summer	
Box Canyon	10-20 Aug	4
Last Chance	14-21 Aug	4
Harriman State Park	2 Aug, 9 Sep[a]	2
East Harriman	8 Sep[a]	1
Pinehaven-Riverside	4-8 Aug	5
Total	2 Aug-9 Sep	16
	Autumn	
Box Canyon	6-23 Oct	8
Last Chance	5-19 Oct	6
Harriman State Park	22-29 Oct	4
East Harriman	24, 28 Oct	2
Pinehaven-Riverside	24, 26 Oct	2
Total	5-28 Oct	22

[a] Samples collected at night (except 31 May).

Table 2. Estimates of redd abundance (N) and 95% confidence intervals (CI) in sections of the Henrys Fork from Island Park Dam to Last Chance. Estimates were obtained using the computer program DISTANCE; effort was the sum of transect lengths.

Section	Area (m^2)	Transects	Effort (m)	Observed redds	N	95% CI
Island Park Dam to USGS gaging station	13,750	13	716.7	22	28	[12; 67]
USGS gaging station to Buffalo River	14,700	10	421.5	1	--	--
Box Canyon	270,000	20	1394	0	--	--
Last Chance	336,800	20	1946	1	--	--

Table 3. Seasonal estimates of juvenile rainbow trout (< 200 mm total length) abundance in study areas of the Henry's Fork in 1995; R denotes the number of recaptures used in estimates.

Section	Sample area abundance [95% confidence interval]	Total abundance [95% confidence interval]	R
	Spring		
Box Canyon	--	12,902 [8,608; 19,811][a]	--
Last Chance	--	1,074 [479;2,684][b]	4
Pinehaven-Riverside	--	4,169 [1,525; 10,422][c]	2
Total	--	18,145 [10,612; 32,917]	--
	Summer		
Box Canyon-upper section	--	2,390 [0; 5,593][a]	--
Box Canyon-lower section	2,220 [1,049; 5,124][c,d]		5
	1,403 [870; 2,388][c,e]	45,072 [23,915; 93,280]	15
Last Chance-upper section	2,062 [1,298; 3,436][c,d]	26,691 [16,802; 44,477]	16
Last Chance-lower section	3,650 [1,106; 6,637][c,e]	55,438 [16,798; 100,805]	1
Total	--	129,596 [57,515; 244,155]	--
	Autumn		
Box Canyon-upper section	--	6,660 [0; 20,160][a]	--
Box Canyon-lower section	1,002 [734; 1,406][c,d]	23,641 [17318; 33,173]	38
Last Chance-upper section	2,255 [1,802; 2,907][c,d]	29,190 [23,326; 37,630]	67
Last Chance-lower section	2,042 [1,438; 3.003][c,e]	31,015 [21,841; 45,611]	29
Harriman State Park[f]	1,234 [777; 2,057][c,d]	13,368 [8,418; 22,284]	16
East Harriman	--	15,752 [4,773; 28,640][b]	1
Total	--	119,626 [75,676; 187,498]	--

Table 3.-Continued.

[a] Bank removal extrapolation + modified Schnabel estimate
[b] Lincoln-Petersen estimate.
[c] Modified Schnabel method.
[d] Sample area 1.
[e] Sample area 2.
[f] 1.7 km section downstream of Railroad Bridge.

Table 4. Number of juvenile rainbow trout marked with visible-implant elastomer marks and number of sampling dates per section.

	Number marked (marking period, d)		
Section	Spring	Summer	Autumn
Box Canyon	430 (8)	224 (4)	645 (8)
Last Chance	144 (6)	285 (4)	566 (6)
Harriman State Park	17 (4)	73 (2)	312 (4)
East Harriman	12 (3)	10 (1)	352 (2)
Pinehaven-Riverside	198 (6)	88 (5)	43 (2)
Total	801 (27)	680 (16)	1918 (22)

Table 5. Mark and recapture sections of juvenile rainbow trout (R=recaptures) between seasons and between sections within a season in 1995. Sections are as follows: 1. Box Canyon, 2. Last Chance, 3. Harriman State Park, 4. East Harriman, and 5. Pinehaven-Riverside.

R	Marking section	Recapture section
	Spring	**Spring**
1	2	5[a]
	Spring	**Summer**
5	5	5
	Summer	**Autumn**
8	1	1
2	1	4
15	2	2
2	2	1
8	3	3
3	5	5
	Autumn	**Autumn**
1	2	1[b]

[a] Individual moved > 15 km in 18-24 d.
[b] Individual moved > 4 km in 10-14 d.

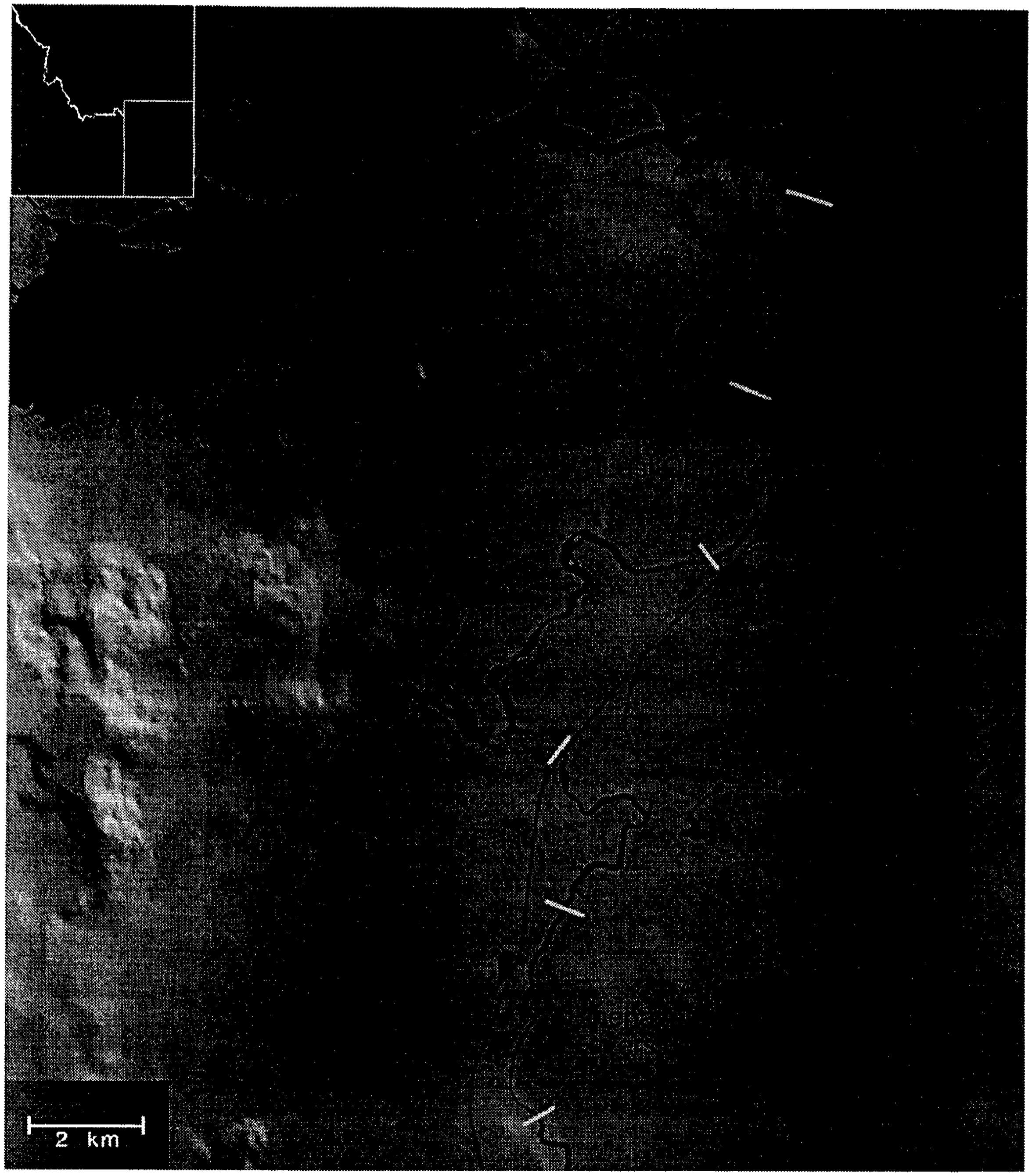

Figure 1. Study sections of the Henrys Fork below Island Park Reservoir: Box Canyon, Last Chance, Harriman State Park, Harriman East, and Pinehaven-Riverside.

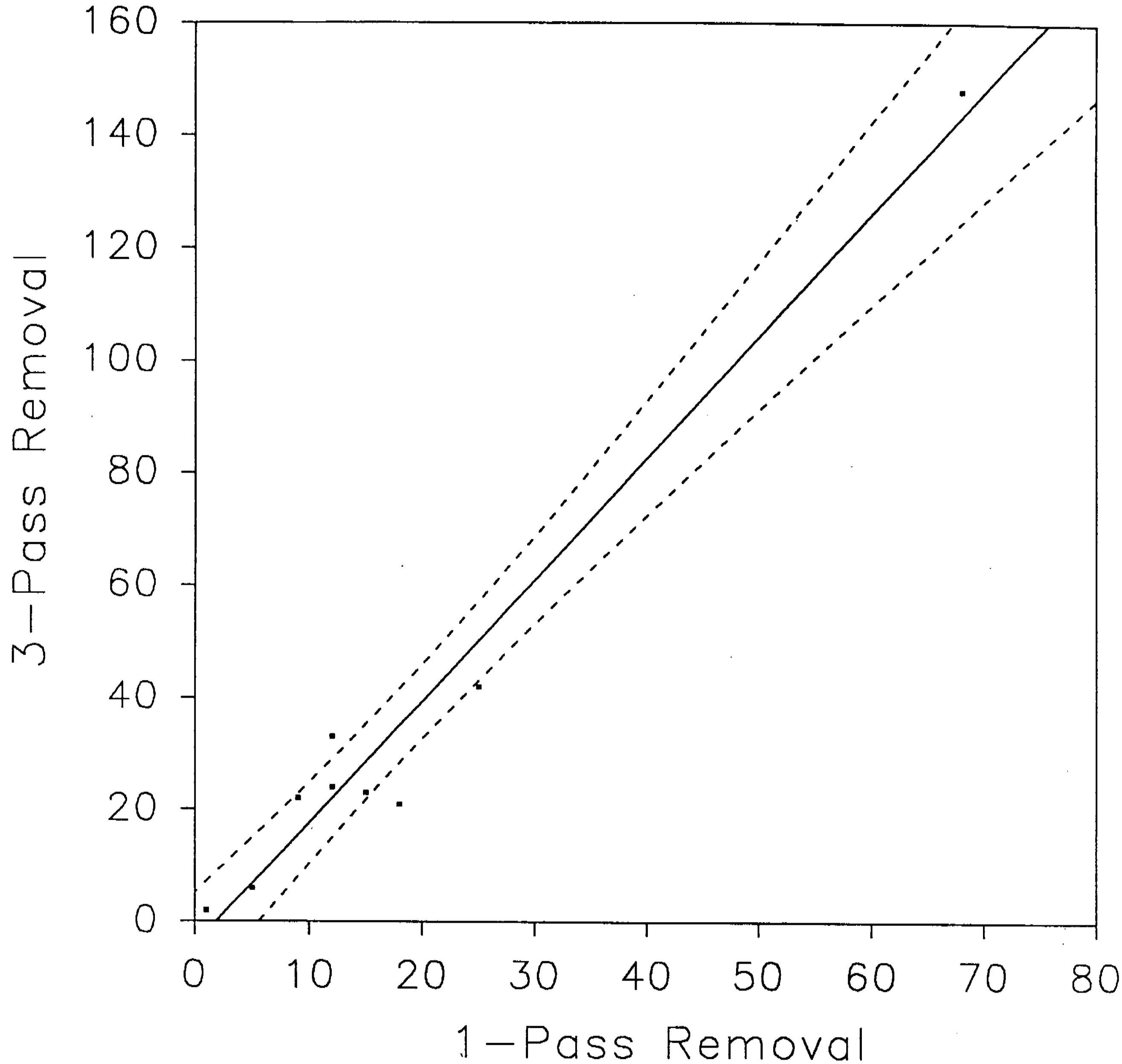

Figure 2. Paired one-pass and three-pass removal estimates from seven 10-m bank sections in Box Canyon and two 10-m bank sections in Pinehaven-Riverside, in autumn, 1995, with fitted linear regression model (solid line) and 95% confidence intervals (dashed lines) (r^2=0.97, *P*=0.0001).

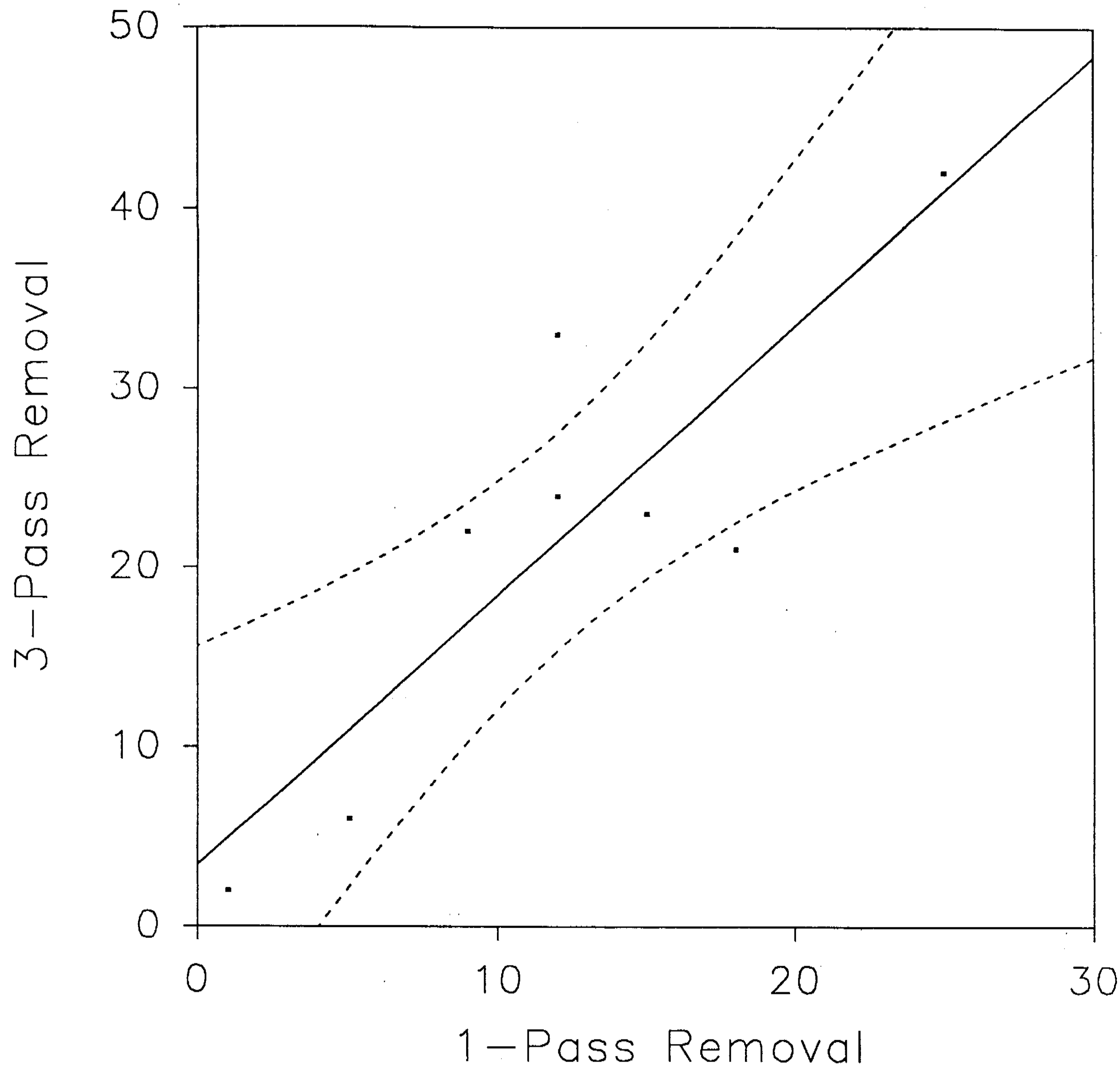

Figure 3. Paired one-pass and three-pass removal estimates from six 10-m bank sections in Box Canyon and two 10-m bank sections in Pinehaven-Riverside, in autumn, 1995, with fitted linear regression model (solid line) and 95% confidence intervals (dashed lines) (r^2=0.75, *P*=0.006).

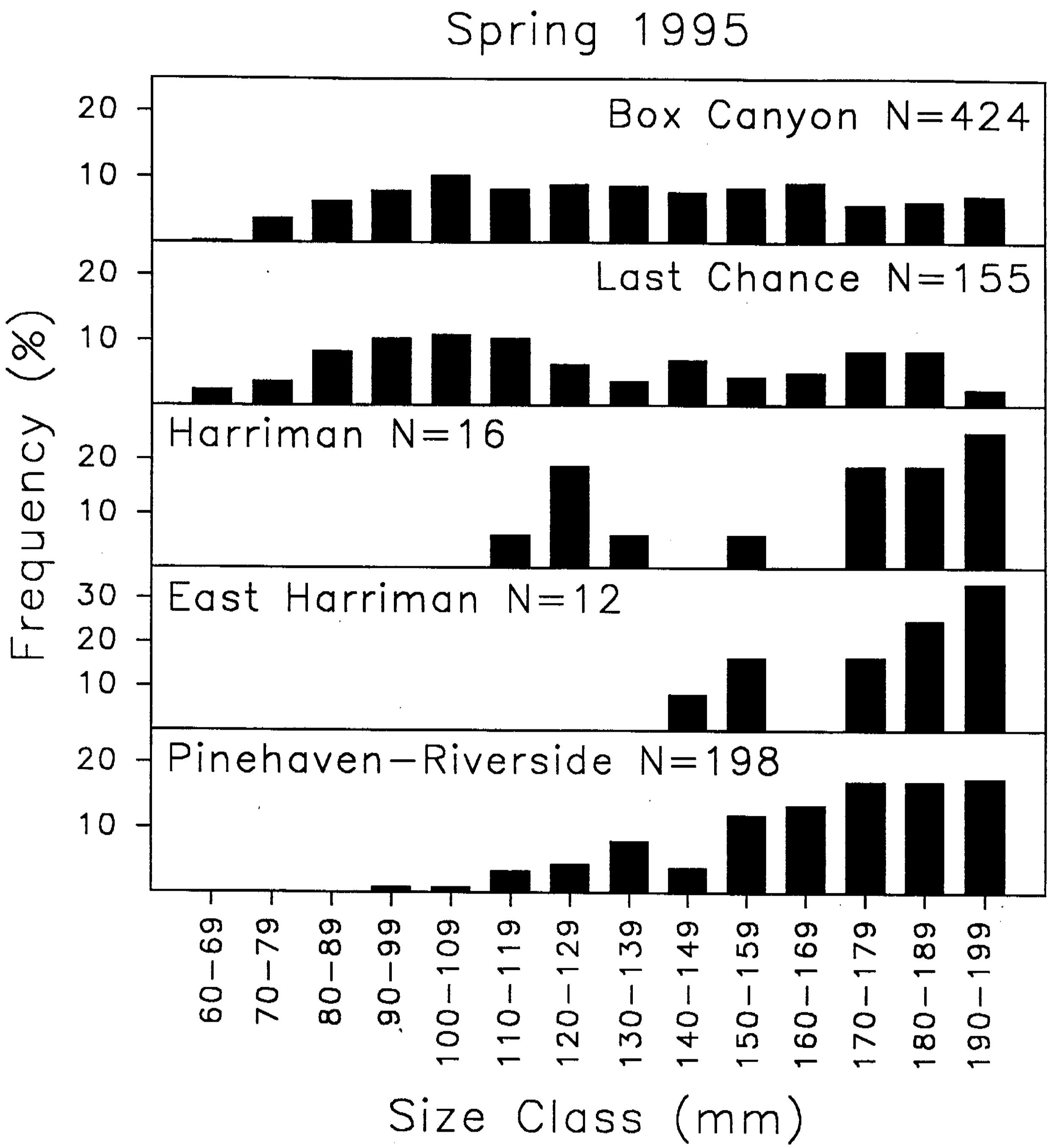

Figure 4. Length-frequency distributions of juvenile rainbow trout collected in Box Canyon, Last Chance, Harriman State Park, East Harriman, and Pinehaven-Riverside in spring, 1995. Note: frequency (%) is not to scale.

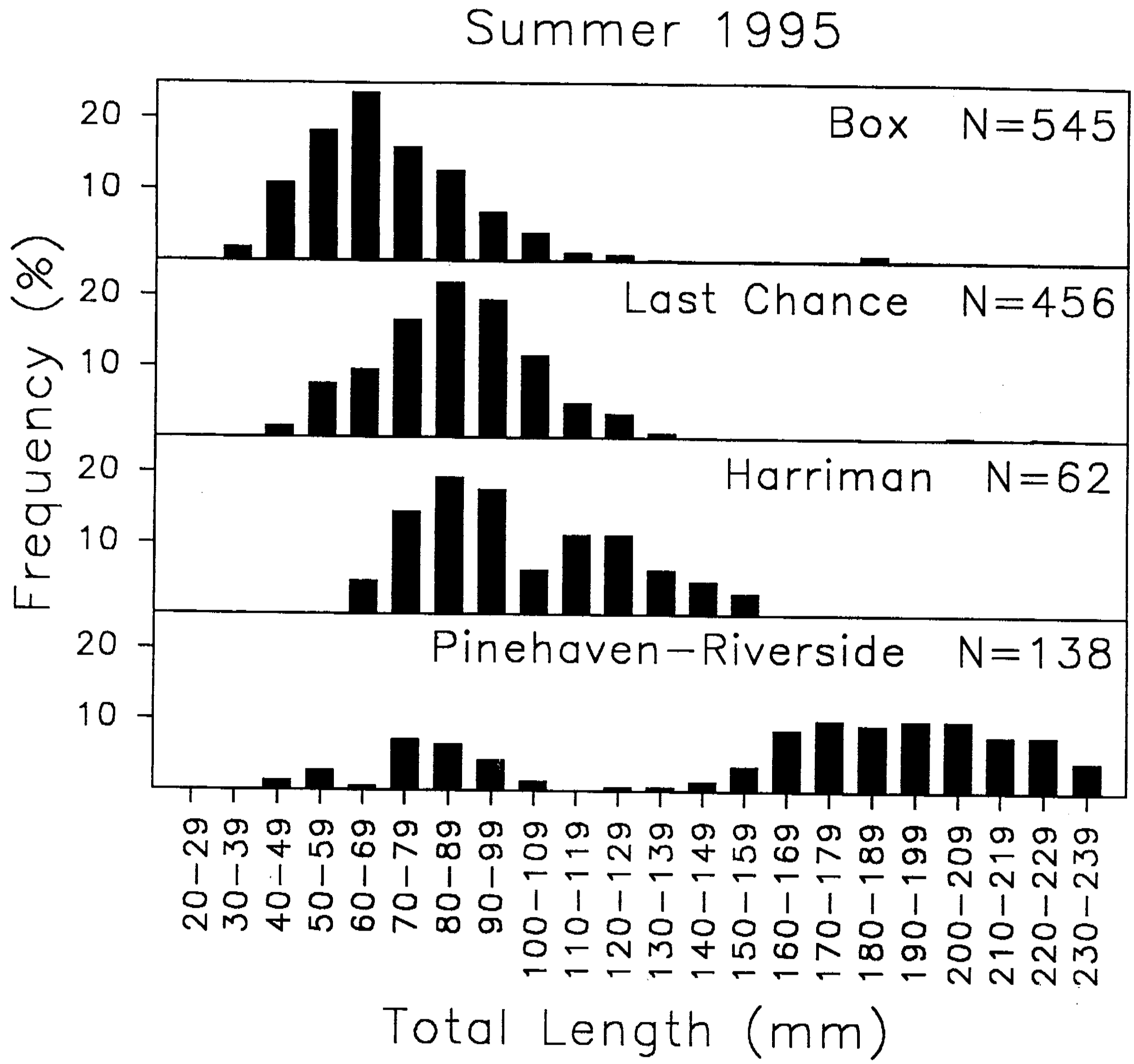

Figure 5. Length-frequency distributions of rainbow trout collected in Box Canyon, Last Chance, Harriman State Park, and Pinehaven-Riverside in summer, 1995.

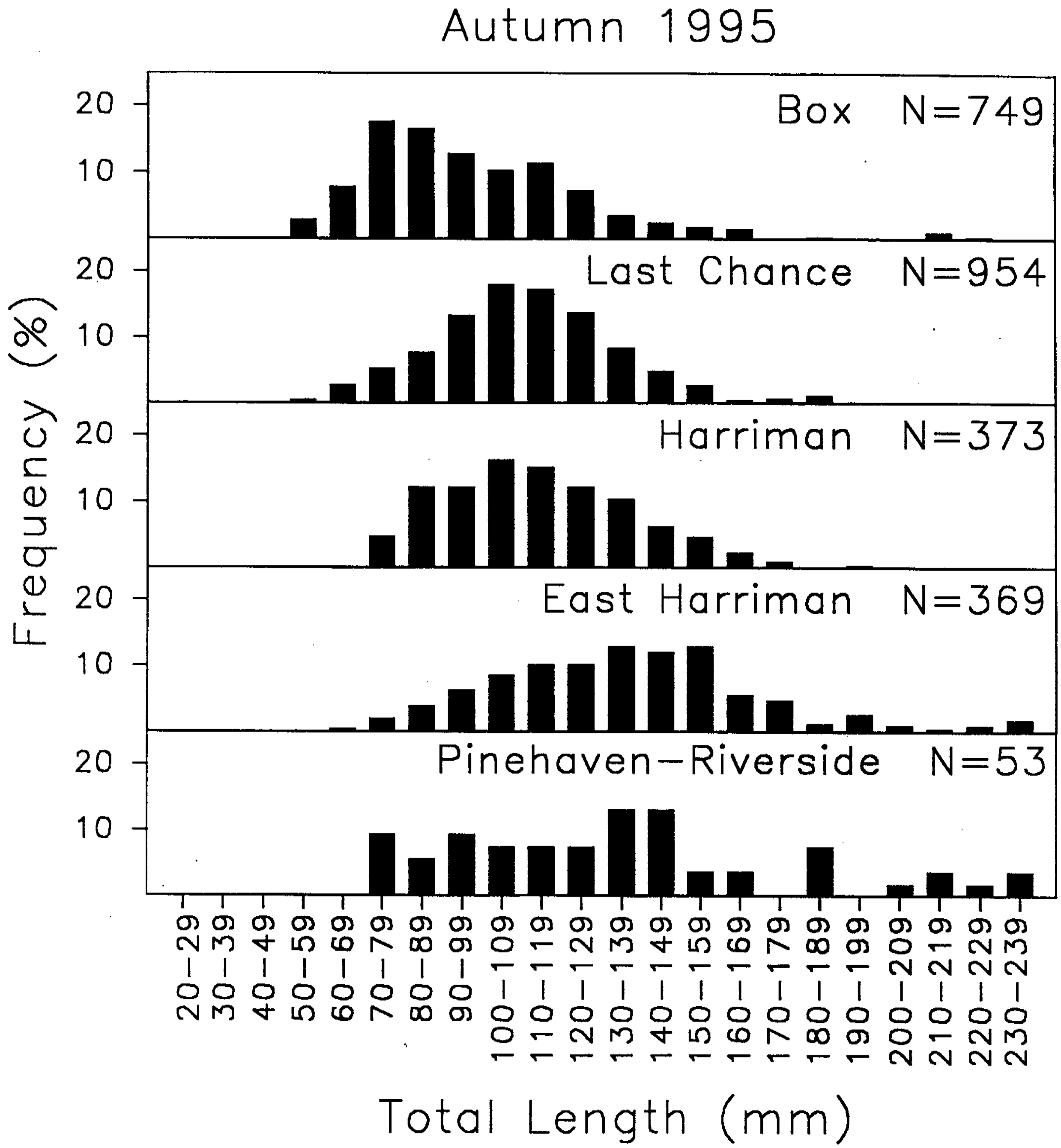

Figure 6. Length-frequency distributions of rainbow trout collected in Box Canyon, Last Chance, Harriman State Park, East Harriman and Pinehaven-Riverside in autumn, 1995.

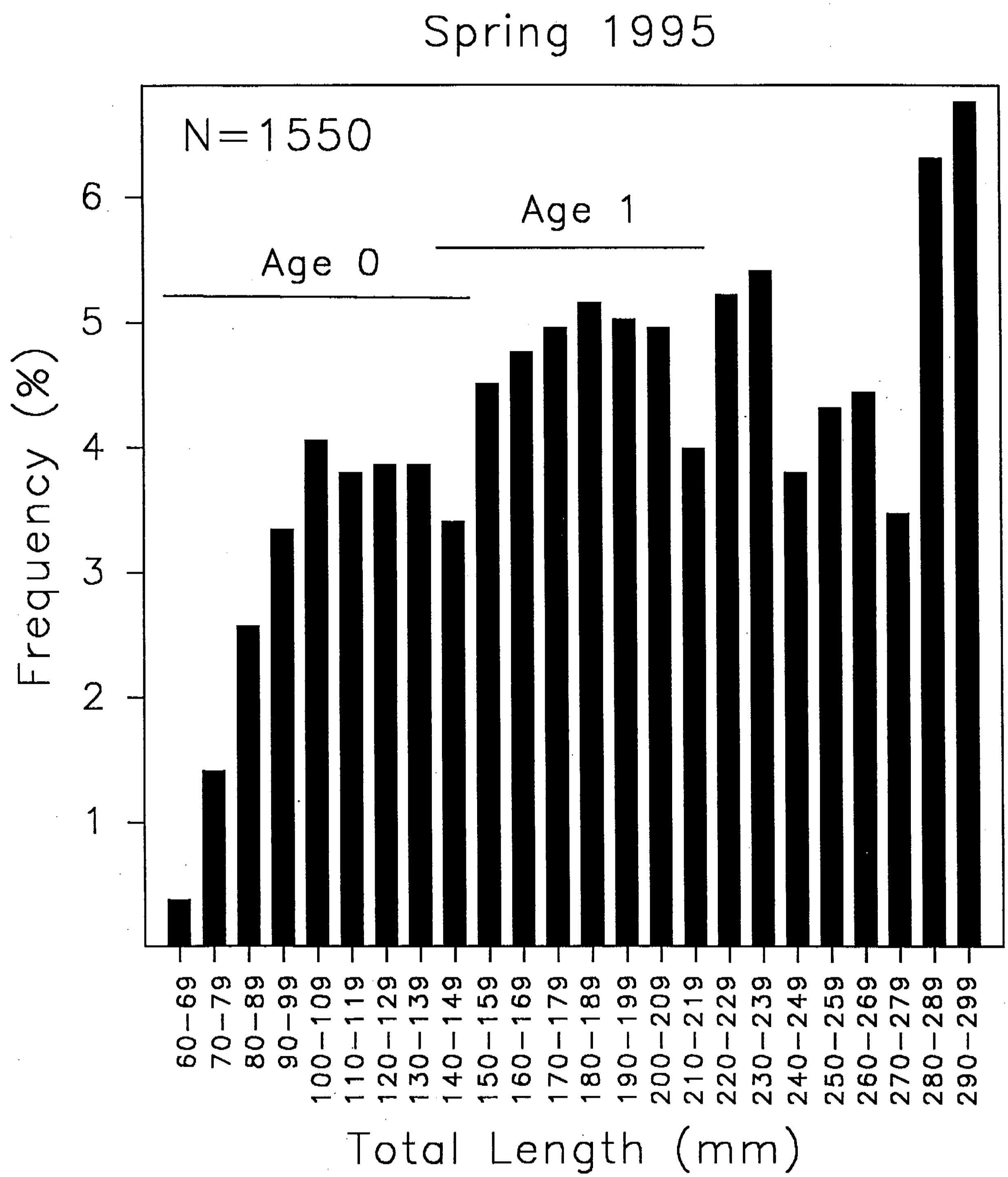

Figure 7. Length-frequency distributions of rainbow trout collected in the Henrys Fork in spring, 1995, with hypothesized distributions of age 0 and age 1 cohorts.

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